

**DESCRIPTION OF THE PREIMAGINAL STAGES OF *PYRACTOMENA*
BOREALIS (RANDALL, 1838) (COLEOPTERA: LAMPYRIDAE)
AND NOTES ON ITS BIOLOGY**

MIGUEL ARCHANGELSKY AND MARC A. BRANHAM

The Ohio State University, Museum of Biological Diversity, 1315 Kinnear Rd., Columbus, OH 43212-1192, U.S.A. (e-mail: branham.24@osu.edu); Current address for (MA): Urquiza 1132, 1638 Vicente Lopez, Buenos Aires, Argentina.

Abstract.—The preimaginal stages of *Pyractomena borealis* (Randall 1838) are described and illustrated. Information on the biology is also included. A detailed description of the functional morphology of the holdfast organ of the larva is presented together with a schematic illustration, step by step, of the eversion process. Instructions on rearing techniques are also provided.

Key words: Lampyridae, firefly, *Pyractomena borealis*, larvae, pupae, biology, holdfast organ, rearing

Resumen.—Los estadios preimaginales de *Pyractomena borealis* (Randall 1838) son descritos e ilustrados. Se incluye información sobre la biología de esta especie. También se presenta una descripción detallada de la morfología funcional del órgano “holdfast” de las larvas de esta especie, así como una ilustración esquemática, paso a paso, del proceso de eversion. También se proveen instrucciones de cría para esta especie.

It is surprising that the biology of fireflies, a group of beetles that has received so much attention from a behavioral point of view, are still poorly known. Another aspect of this family of beetles that has also been largely neglected is the study of their immature stages. There are few descriptions of larvae from the New World and, with a few exceptions, most of those descriptions are very brief.

Of the 18 Nearctic genera of Lampyridae (Poole and Gentili 1996), only eight have described immature stages. Four of those genera are known from immatures described in Europe (*Lampyris* Geoffroy and *Phausis* LeConte) and Brazil (*Aspisoma* Laporte and *Bicellonycha* Motschulsky) (Vo-

gel 1912, Haddon 1915, Bugnion 1929, Costa et al. 1988). It should also be mentioned that the larvae of several genera are difficult to tell apart, especially those of the tribe Photinini (LaBella and Lloyd 1991). There are two main obstacles preventing an easy association of adults with immatures. The first is the apparent difficulty in rearing lampyrids in the laboratory; the other is that females are usually difficult to collect. Rearing lampyrids is not as difficult as it may appear, and several genera such as *Pyractomena* Melsheimer, *Photinus* Laporte and *Photuris* Dejean have been reared successfully in the laboratory (Williams 1917, McLean et al. 1972, Buschman 1977). The second obstacle, that of finding females,

can be overcome by collecting larvae in the field, and rearing them through to the adult stage. One final problem is that some species spend multiple years as larvae (Williams 1917, Hess 1920, Buschman 1977) and, in at least some cases, such as *Pyractomena lucifera* Melsheimer, the life cycles can be heterovoltine (Buschman 1977).

Green (1957) revised the Nearctic species of *Pyractomena* Melsheimer and also included larval and pupal descriptions of four of the 16 Nearctic species: *P. ecostata* (LeConte), *P. angulata* (Say), *P. borealis* (Randall), and *P. punctiventris* (LeConte). His descriptions are brief and make reference to general body shape and coloration. No details of features such as the head capsule or the mouthparts are included; furthermore, in the case of *P. borealis*, the description is based on three larval exuviae. Buschman (1977) studied the biology of some selected fireflies, among them *Pyractomena lucifera* and provides a detailed description of the life cycle of this species under both laboratory and natural conditions (Buschman 1977, 1984).

MATERIALS AND METHODS

Mature larvae of *Pyractomena borealis* were collected by MA on March 23, 1994 at Cedar Bog Natural Preserve (Ohio). They were kept in a small plastic container with a wet paper towel, and brought to the laboratory. A small terrarium was made with a rectangular plastic container (12 × 20 × 7 cm); part of the lid was cut out and replaced with a fine mesh to allow gas exchange and to avoid an excessive build up of humidity. Fine sand mixed with some soil (80% sand and 20% soil) was used as the substrate and, on top, small pieces of bark were added. The substrate was kept moist during the entire rearing process. Small aquatic snails were offered to these larvae, but those were refused and pupation took place soon after the larvae were collected. No special requirements were necessary for pupation. Several males and one female emerged from the pupal exuviae,

and two days after copulation the female laid a cluster of eggs. Newly emerged larvae were offered snails which they accepted, and throughout the rearing process they were maintained on the same diet. In order to keep the container clean, the empty shells were removed every other day. The culture was subdivided as larvae reached the third instar to avoid an overcrowded environment (however, cannibalism was never observed).

Several larvae of each instar were fixed in boiling water, and stored in 75% alcohol. All the last (fifth) instar larvae were fixed by the end of July. Pupae were fixed in the same way, but right after fixation they were punctured in two or three places with a minuten pin, thus preventing the swelling of the pupae and allowing the maintenance of their natural shape.

To study the larval morphology, several specimens were cleared in lactic acid and dissected in order to obtain different parts of the body (head capsule, mouthparts, holdfast organ, etc.). These were arranged on slides using Hoyer's as the mounting medium. Drawings were done using a dissecting microscope (Wild M5) and a compound microscope (Wild M20), both with a camera lucida. The schematic illustration of the eversion process of the holdfast organ was done using MacDraw II, version 1.1.

Pyractomena borealis (Randall)

Description of fifth larval instar.—Body elongate, fusiform, slightly flattened dorsoventrally (Fig. 1). Cuticle shiny on sclerotized areas, granulose with short clubbed setae on clear granules, areas with dark granules lacking setae (Fig. 8). Color pattern variegated, ranging from light brown to dark brown. Length: 17.0 to 22.0 mm. Length of remaining instars: first = 3.5 to 4.5 mm; second = 7.0 to 8.5 mm; third = 9.0 to 11.0 mm; fourth = 13.0 to 16.0 mm.

Head capsule: Prognathous, small, subcylindrical, twice as long as wide (Fig. 2); retractile within the thorax. Head capsule not fused ventrally (Fig. 3). Labrum and

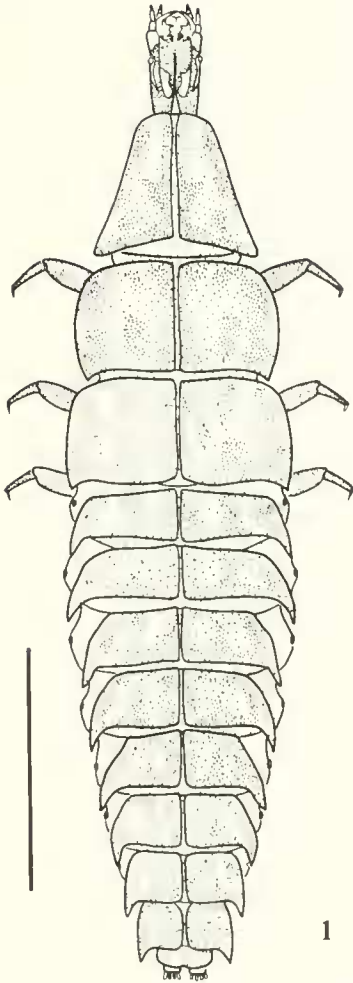


Fig. 1. *Pyractomena borealis*, fifth instar larva, habitus. Scale bar = 5.0 mm.

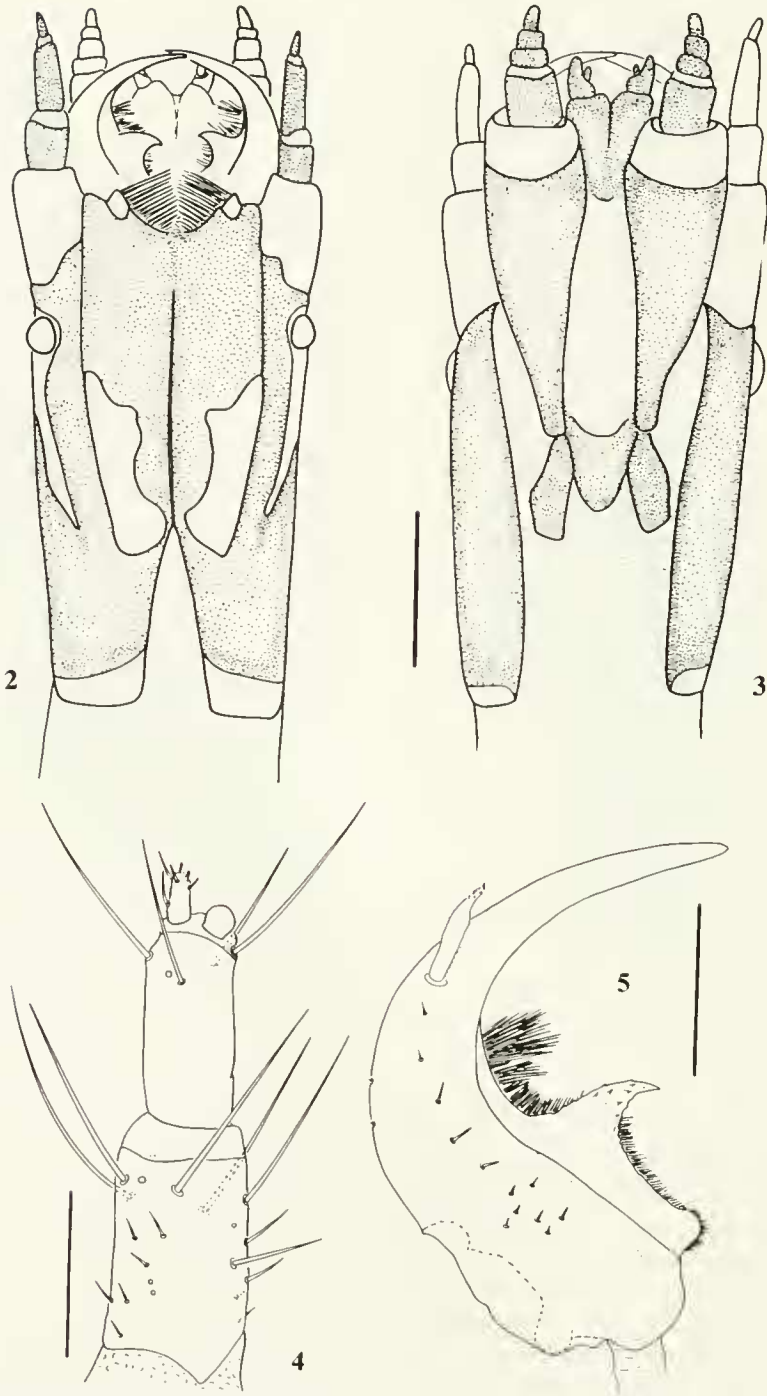
clypeus fused. Head with 3 internal ridges, 1 along middle of head, extending almost to distal edge; 2 lateral ones originating behind inner margins of antennae, extending back and disappearing at basal third of head capsule. Epicranial suture, in fifth-instar larvae, present as a fine line, V-shaped, extending forward from base of middle internal ridge to base of lateral internal ridges; non-functional (head capsule not split open between last larval instar and pupal stage). Occiput forming a V-shaped incision dorsally, from where median internal ridge originates. One pair of lateral stemmata,

posterior to base of antennae. Epipharynx formed by two oval plates covered by transverse rows of microtrichiae, and an anterior brush of long, slender setae that project past labroclypeal margin.

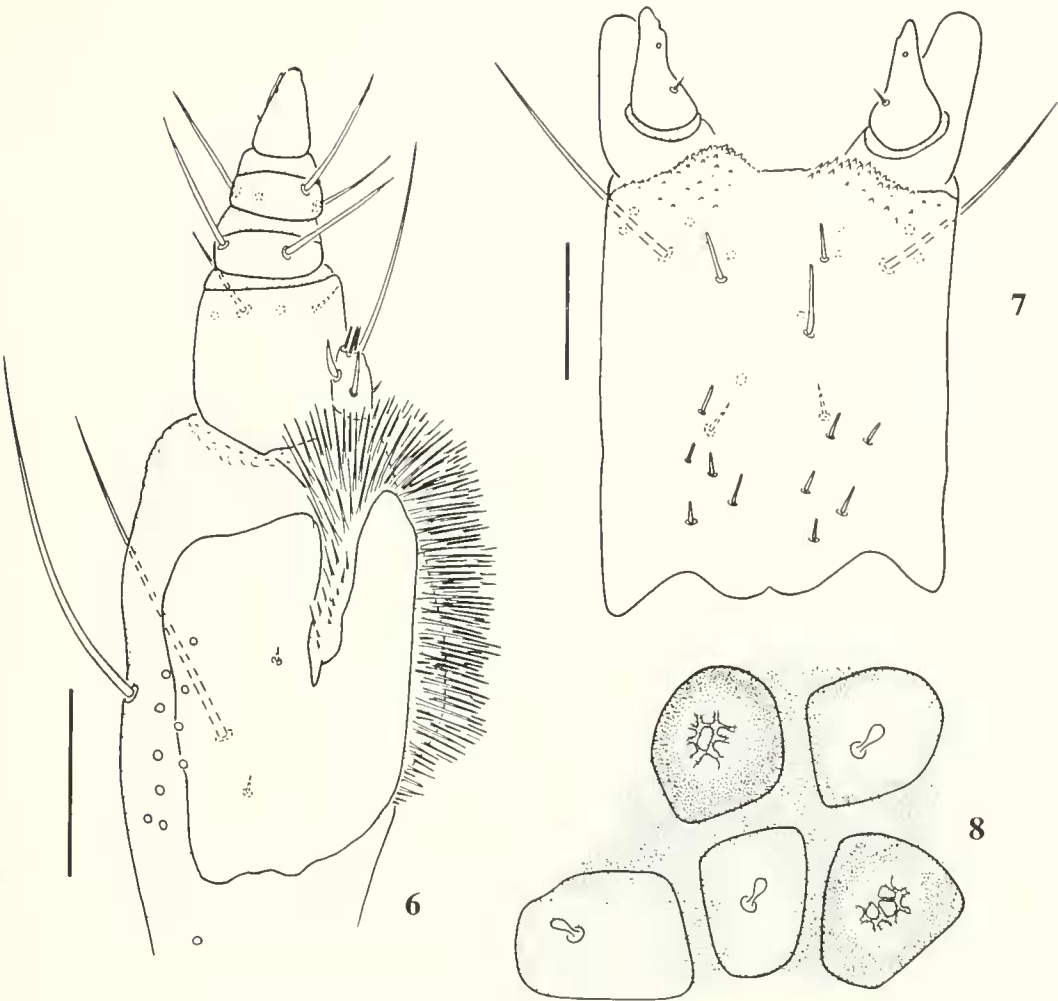
Antenna: Three-segmented, partially retractable within membranous base (Fig. 4); originating on latero-apical edges of Head capsule. Basal segment widest, attached to membranous base, carrying five long subapical setae distributed as follows: two dorsal, two ventral and one lateral; several other short setae also on dorsal and lateral surfaces. Second segment as long as first, narrower, with four long subapical setae, carrying a large globular sensorium, half length of third antennal segment (longer in first instar larva). Third segment much smaller, with several short setae and a pair of small cuticular projections.

Maxilla: Elongated, closely attached to labium, forming an homogeneous structure loosely connected to head capsule (Fig. 3). Cardo narrowly subquadrate, covered by dense pubescence. Stipes as an elongate triangle, broader on distal end, ventral surface more sclerotized than dorsal, which is incompletely sclerotized (Fig. 6); galea two-segmented, basal segment short, distal segment carrying several short setae and one long apical seta that reaches base of last palpal segment; lacinia reduced, appearing as a thick brush of cuticular spines, covering base of galea and inner margin of stipes (more reduced in first instar larva). Palpus four-segmented, basal segment largest, as long as other three combined, with two ventral setae; second and third segments short, wider than long, second segment with two long dorsal setae and third segment with one dorsal and two lateral long setae; distal segment subconical.

Mandible: Symmetrical, strongly falcate, with an inner channel opening subapically on outer edge (Fig. 5). Retinaculum present, forming a sharp inner tooth on basal third of mandible, with several sharp, short, triangular spines. Ventral surface of mandible with a dense brush of slender spines pro-



Figs. 2-5. *Pyractomena borealis*, head of fifth instar larva. 2, Dorsal view. 3, Ventral view. Scale bar = 0.5 mm. 4, 5, Fifth instar larva. 4, Left antenna, dorsal view. 5, Left mandible, dorsal view. Scale bars = 0.2 mm.



Figs. 6–8. *Pyractomena borealis*, fifth instar larva. 6, Left maxilla, dorsal view. 7, Prementum and labial palpi, dorsal view. 8, Detail of the cuticular granules. Scale bars: Fig. 6 = 0.2 mm, Fig. 7 = 0.1 mm.

jecting mediad; dorsal surface with several short setae. One clear, hyaline, long seta or sensory appendage close to outer margin of mandible, just before channel opening carrying several small distal spines.

Labium: Closely attached to maxilla; formed by a short and strongly sclerotized prementum, an elongated and poorly sclerotized mentum, and a small subtriangular submentum. Prementum, in ventral view, with a distal apical cleft (Fig. 3) and a pair of long and slender setae; in dorsal view with a group of small, apical cuticular spines and several short setae. Palpus two-

segmented; basal segment longer and projecting further than second, second segment attached to basal half of first one (Fig. 7).

Thorax: Three-segmented. Prothorax subtriangular, wider at base, containing retracted head when larva in repose. Meso- and metathorax subrectangular. Thoracic tergites subdivided by a sagittal line. Color pattern variegated, ranging from light yellow to dark brown (Fig. 1). All three segments with pleural areas formed by an upper laterotergite, below it an epimeron and episternum separated by a deep pleural suture; mesothoracic laterotergite subdivided,

anterior plate smaller, carrying mesothoracic spiracle. Prosternum large, subpentagonal; meso- and metasterna smaller, narrow, subdivided into an anterior basisternum and a posterior sternellum. A long and soft neck, with two pairs of long and narrow sclerites (one dorsal and one ventral), connects head with prothorax; head retracts completely within this neck. One pair of biforous spiracles present on mesopleura.

Legs: Five-segmented, coxae long and cylindrical; trochanters small, subtriangular in lateral view; femora long and cylindrical; tibiotarsi as long as femora, tapering towards distal end; pretarsi strong, simple, with a pair of stout setae at base. Femora and tibiotarsi with a double row of strong setae on inner margin.

Abdomen: Ten-segmented, segments one to eight similar in shape, becoming narrower towards end; each tergite subrectangular, divided by a sagittal line, with a lateral projection on each side pointing backwards (Fig. 1); ninth segment much smaller, subquadrate, lacking sagittal line and without lateral projections; segment ten as a narrow ring surrounding anal region, carrying holdfast organ. Pleural areas well developed, segments one to seven subdivided, upper plate large, suboval, carrying spiracles, lower plate small, narrowly subtriangular; pleura eight with only one suboval plate carrying a spiracle; pleural areas of segments nine and ten reduced. Abdominal sterna large, subquadrate, narrowing towards end of abdomen. Color pattern similar to that of thorax, variegated. Biforous spiracles present on pleurites one to eight.

Description of pupa.—Slightly curved, ventrally concave; young pupa light brown in color, mature pupa darker. Length: 19.0 to 23.0 mm.

Head: Completely covered by pronotum in dorsal view (Figs. 9, 10), light brown. Eyes large, on sides of head; antennae inserted in front of eyes, closer to center of frons; antenna and mouthparts dark brown.

Thorax: Pronotum large, subtriangular, covering head; light brown with two dark

brown longitudinal bands in disk. Meso- and metanota shorter, subrectangular, carrying wingpads on sides and slightly darker than pronotum. First and second pair of legs fully visible in ventral view; third pair of legs partially covered by wingpads.

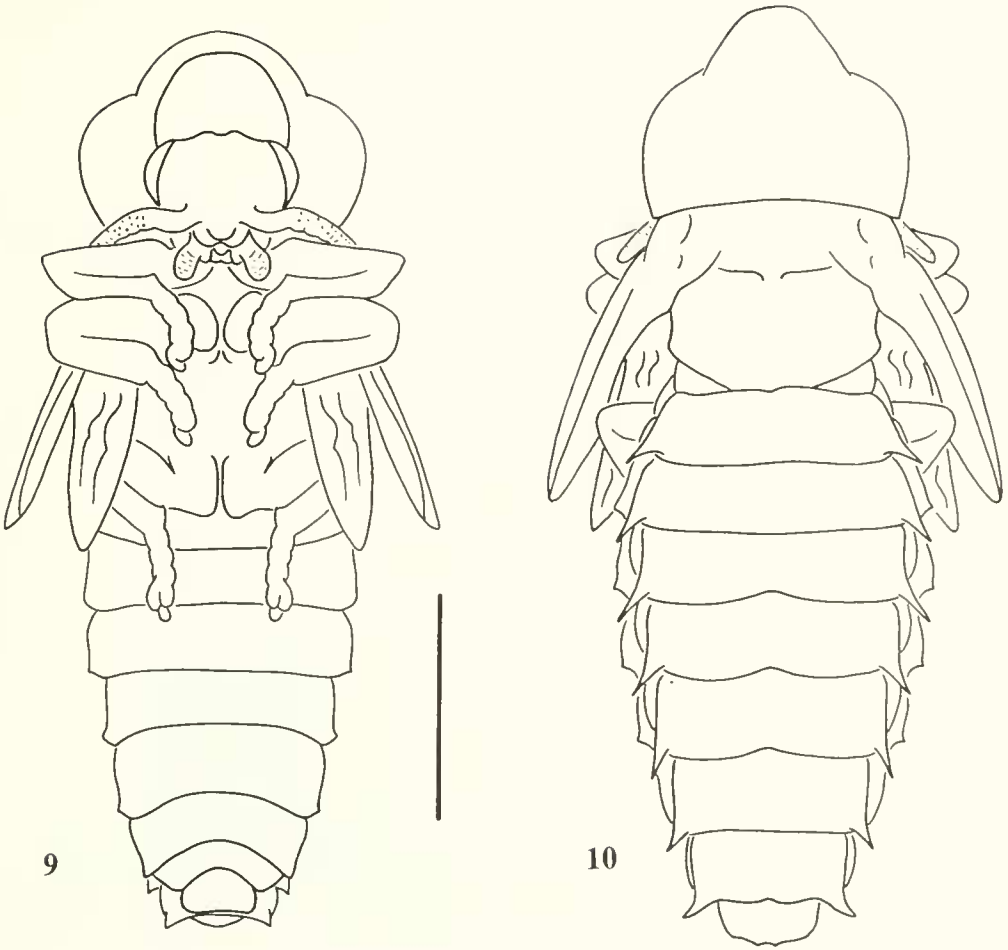
Abdomen: Segments wider than long, light brown. Tergites one to seven similar in shape but becoming narrower after tergite three; subrectangular, with acute projections on postero-lateral corners, and becoming smaller toward abdominal apex. Sternite one covered by legs and wingpads, segment two partially visible, remaining sternites fully visible. Segment eight small, partially visible in dorsal view, tergite with a short acute projection on each posterolateral corner.

Spiracles: Seven pairs of functional spiracles; first in pleuron of mesothorax, remaining six on abdominal segments two to seven.

BIOLOGY

The following description of the life cycle of *Pyractomena borealis* was obtained from specimens collected in the field and reared in the laboratory. In many cases, specimens reared in the laboratory may have different developmental times than those living in natural habitats due to changes in the light:dark cycle (Buschman 1977, personal observations). In any case, *P. borealis* seems to be an annual species and, in Ohio, adults are collected in the spring. Green (1957) collected pupal exuviae in May (Minnesota), and April (Maryland); these agree with our dates for Ohio. In the same paper Green lists the collection dates for adult specimens in several states, all ranging from March (southern states) to July and August (northern states and Canadian provinces).

Several mature larvae were collected, on the bark of trees at heights of 2 to 5 feet above the ground. They did not feed, suggesting that they either overwintered as mature fifth instar larvae or prepupae. The lar-



Figs. 9–10. *Pyractomena borealis*, pupa. 9, Ventral view. 10, Dorsal view. Scale bar = 5.0 mm.

vae were very active, and they pupated five to six days after being brought into the laboratory. Prepupae attached themselves to the bark using the holdfast organ, pupating exposed instead of digging a pupal chamber as do many other lampyrids, as has also been reported by other authors (Balduf 1935, Buschman 1977, 1984, LaBella and Lloyd 1991). The prepupae, and latter the pupae, hung vertically, with the head pointing downward and the venter facing the bark. The larval skin remained attached to the substrate, surrounding the terminal abdominal segments of the pupa. Adults emerged in 4 to 5 days. Males were first to emerge. The only female reared was ap-

proached by males soon after emergence, and her cuticle was not completely sclerotized during copulation. Eggs were laid three to four days after mating, in cracks of the bark or under pieces of bark. The only clutch of eggs obtained consisted of approximately 100 eggs.

First instar larvae emerged one month after the eggs were laid. Larvae of all instars fed on snails. Aquatic snails of the genera *Physa* Draparnaud and *Gyraulus* Agassiz were used in the laboratory. Early instars to the third, showed gregarious feeding habits. Small groups of three to six larvae were seen feeding together on the same prey. Since larvae have a protractable head and a

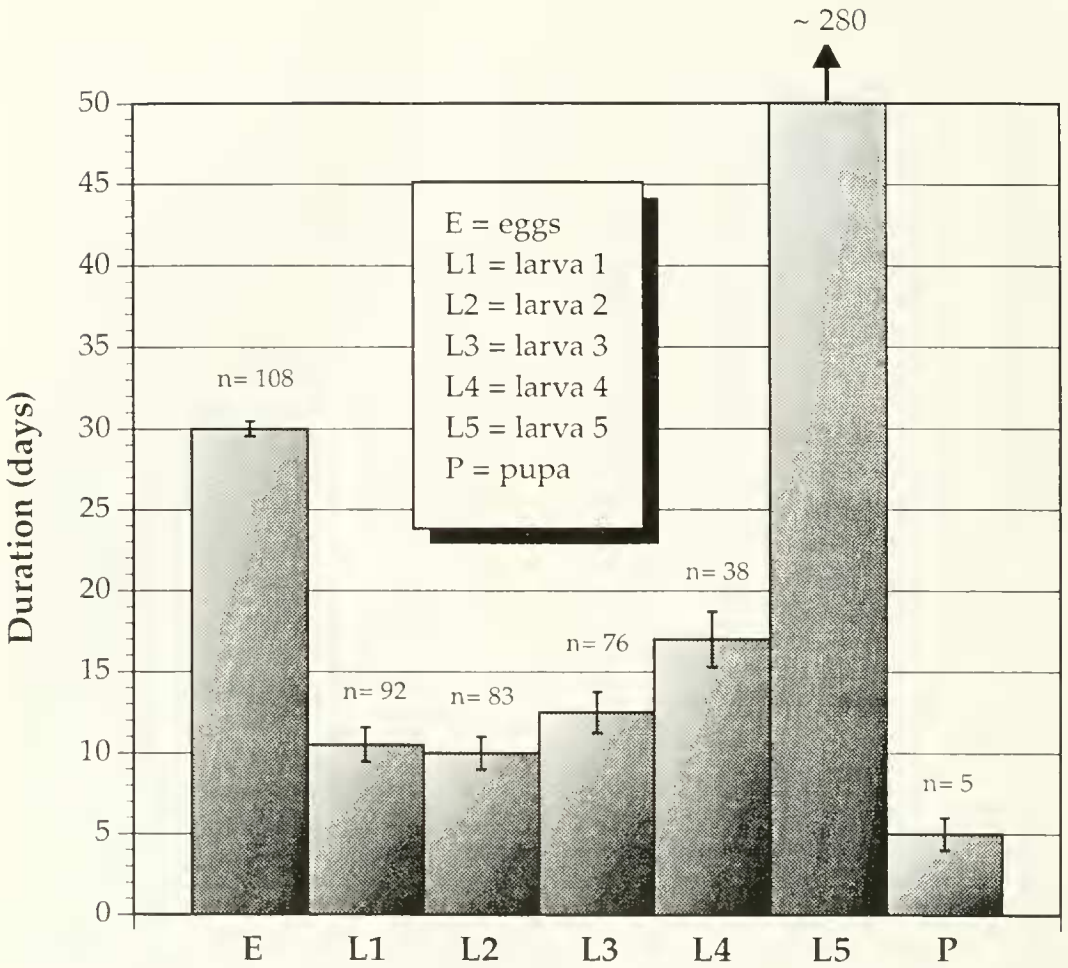
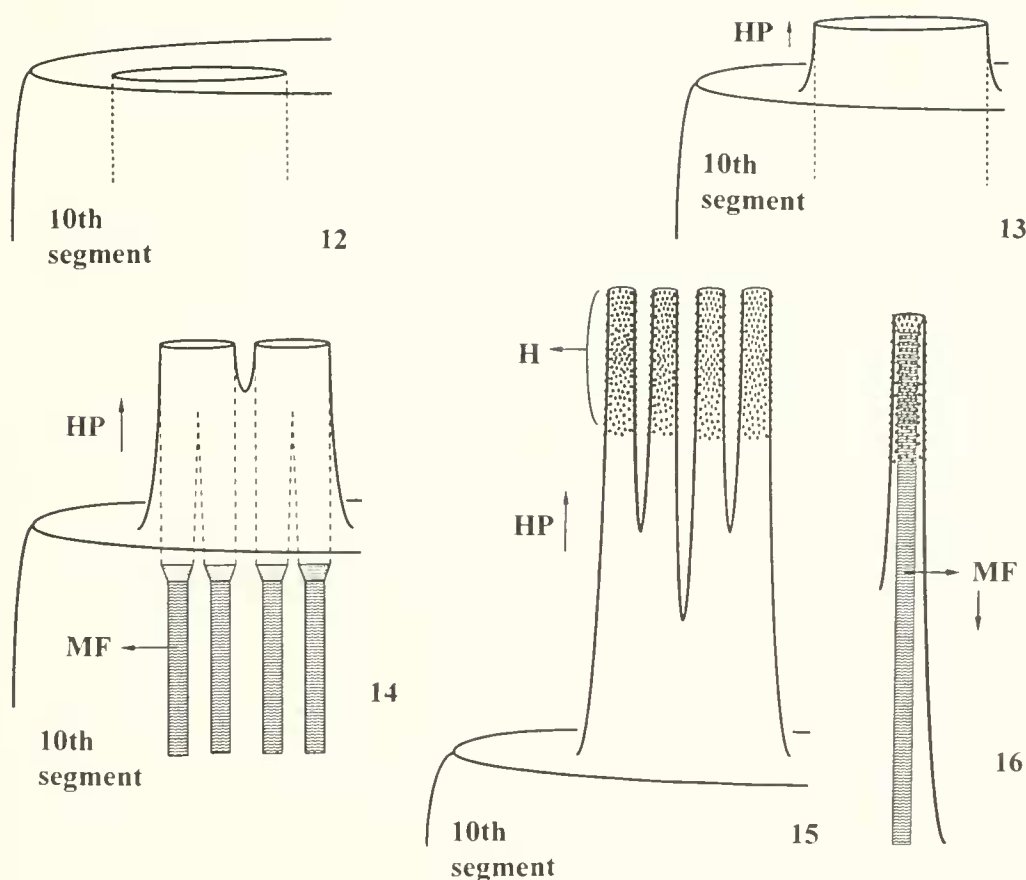


Fig. 11. Mean duration (in days) of the preimaginal stages of *Pyrractomena borealis* (n = number of larvae). Duration of the fifth instar is approximate.

long neck, up to twice the length of the head, they can extend it forward and eat the contents of retracted snails. They also injected extraoral digesting fluids through their mandibles. After feeding they used the anal holdfast organ to groom their heads, mouthparts, and neck. Before moulting to the next instar, larvae stopped feeding and hung themselves from the bark or walls of the container using the holdfast organ, similar to what they did between the prepupal and pupal stages. The holdfast organ was also used to aid locomotion while wandering around on the bark.

The duration of each stage was very constant between larvae and is summarized in Fig. 11. First and second instars moulted after 9 to 11 days. The duration of subsequent instars increased with age: third instar larvae 12 to 13 days, fourth instars 16 to 18 days, and, fifth instar larvae were fixed after about 40 or 50 days. The approximate duration of the fifth instar, based on the date when the larvae at Cedar Bog were collected, would be around 280 days. This species has five instars (under laboratory conditions), and the last instar seems to be the one that overwinters. We have no infor-



Figs 12–16. Schematic representation of the eversion process of the holdfast organ; see text for a detailed description. 12, Holdfast organ retracted. 13, First step of the process due to haemolymph pressure (HP). 14, First branching of the holdfast organ, the internal muscle fibers (MF) are attached to the end of the finger-like appendages. 15, 16, Schematic representation of the eversion process of the holdfast organ; see text for a detailed description. 15, Holdfast organ completely everted due to haemolymph pressure (HP), the cuticular hooks (H) cover the distal two-thirds of each finger-like appendage. 16, Detail of one finger-like appendage with internal muscle fiber (MF) responsible for retraction of appendage.

mation on where the larvae overwinter, but it may be among plant debris at the base of the trees.

FUNCTIONAL MORPHOLOGY OF THE HOLDFAST ORGAN

The holdfast organ (also called caudal appendage, caudal grasping organ, and tail organ) has been mentioned or described by several authors (Targioni Tozzetti 1866, Bugnion 1922, 1929, 1933, Blair 1927, Okada 1928, Balduf 1935, Peterson 1951, Costa et al. 1988, LaBella and Lloyd 1991, Tyler 1994), and it seems to be unique to

lampyrid larvae (within the elateroid lineage), being absent in related families. Similar structures are present in some carabids and staphylinoids (Silphidae), but these seem to be convergencies. As mentioned above, the holdfast organ has different functions: aiding the larvae in locomotion; cleaning their heads and mouthparts after consuming prey; and attaching themselves to the substrate between moults and during the pupal stage.

This organ is composed of a series of eversible, digitiform structures that project from the membranous area of the last ab-

dominal segment (10th), surrounding the anal region. There are five such structures on each side of the tenth segment. Figures 12–16 show a schematic representation of the eversion process of one such structure. The finger-like appendages first appear as a single tube when they begin to evert (Figs. 12, 13), via haemolymph pressure (HP). As eversion proceeds, these tubes fork once (Fig. 14), and then a second time (Fig. 15); this produces four terminal processes, each one covered on its terminal two thirds with microscopic hooks (H). These hooks point outwards and forwards, and attach easily to any substrate on which the larvae walk. They are also useful for removing mucus and other residues left on their head, mouthparts, and neck after feeding on snails. This last function is extremely important since the head is usually retracted within the prothorax, and any dirt or sticky residue would affect this retraction.

On the inside of each of these caudal filaments is one muscle fiber (MF) (Figs. 14, 16), which is responsible for the retraction of each finger-like appendage. During retraction, the hooks point inwards and backwards, thus avoiding being caught on the membranous cuticle of these appendages.

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